RCA

Advance Application Note

TWO TRANSISTOR STEREO AMPLIFIERS USING RCA 40050 AND 40051 ALLOY-JUNCTION OUTPUT TRANSISTORS

by

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TWO TRANSISTOR STEREO AMPLIFIERS

USING RCA 40050 AND 40051

ALLOY-JUNCTION OUTPUT TRANSISTORS

The RCA 40050 and 40051 alloy-junction power transistors are specially designed for use in the output stages of high-fidelity amplifiers and other commercial audio-frequency amplifier applications. The use of these transistors in a suitable circuit arrangement makes possible the design of economical audio amplifiers that provide high gain with low distortion and that have wide, flat frequency responses.

This note describes a three-stage transistor stereophonic amplifier (5 watts per channel) that uses 40050 transistors in its output stage and a four-stage transistor stereophonic amplifier (15 or 25 watts per channel) that uses 40051 transistors in its output stage. These output transistors are grouped and labeled according to their characteristics so that it is possible to use transistors having approximately the same gain in both channels of a stereo amplifier. These amplifiers, which are intended for commercial "box"-type applications, demonstrate the excellent performance that can be achieved in low-cost systems.

Three-Stage Amplifier

The three-stage amplifier shown in Fig. 1 is designed for operation with an input from a conventional ceramic phonograph pickup and with an 8-ohm load impedance connected across its output terminals. Each channel of the amplifier uses a low-noise 2N2613 transistor in the input stage, a 2N2953 transistor in the driver stage, and two 40050 transistors in the class B output stage.

This three-stage amplifier develops 5 watts of output power from each channel with very little distortion, clips at 8 watts for a one-kilocycle input, and has an industrial high-fidelity manufacturer's (IHFM) music rating of 20 watts. At average record levels, the full output of 5 watts per channel is obtained for a drive input provided by a typical 0.5-volt, 1000-picofarad ceramic pickup. Detailed performance data for the amplifier are given in Table I.

Four-Stage Amplifier

The four-stage amplifier shown in Fig. 2 is designed for operation with a ceramic pickup or an FM-stereo type of input. At the clipping level, this amplifier can supply 15 watts of output power per channel into an 8-ohm load impedance or 25 watts per channel into a 4-ohm load impedance. Each channel uses a low-noise 2N2613 transistor in the input stage, a 2N2614 transistor in the preamplifier stage, a 2N591 transistor in the driver stage, and a class B output stage that employs two 40051 alloy-junction power transistors.

In the 15-watt mode of operation, the amplifier has an IHFM music rating of 50 watts, and sensitivity such that each channel supplies the full 15 watts of output power to its 8-ohm load impedance for an input of 0.28 volt. When the amplifier is operated to deliver 25 watts of output into a 4-ohm load impedance, it has an IHFM music rating of 75 watts.

For the 25-watt mode of operation, however, the feedback around the output and driver stages must be increased by 4 to 5 db to provide performance comparable to that obtained at 15 watts. In addition, it is desirable to provide about 5.2 db more signal because the output level is 2.2 db higher and the 4-ohm load provides 3 db less gain than an 8-ohm load. The desired extra signal can be readily obtained by use of one of the new high-capacitance pickups recently introduced to the industry. A 0.01-microfarad, 100-millivolt pickup used with the input circuit shown in Fig. 3 can provide more than 10 db of extra signal and also improve the signal-to-noise ratio. When this circuit is used, the full power output of 25 watts per channel can be obtained for a 100-millivolt input.

Table II gives detailed performance data for the four-stage amplifier.

Tone and Loudness Controls

In both amplifiers, series resistances are used to obtain a high input impedance. It is possible to use this technique and still maintain satisfactory signal-to-noise ratios because of the excellent noise characteristics of the 2N2613 input-stage transistors. The high input impedance of the amplifiers obviates the need for equalization of the ceramic pickup and also permits the use of a simple, full-range treble control that has zero insertion loss.

The three-stage amplifier also uses a zero-insertion-loss bass control. This control provides bass-cut action by loading the ceramic pickup at low frequencies. The combination of this action and the bass-boost action provided by the two feedback loops has the same effect as a conventional cut-and-boost control except that a narrower range is obtained. However, the narrower range is generally considered acceptable in the type of applications for which the three-stage amplifier is intended.

The four-stage amplifier uses a full-range, insertion-loss type of cut-and-boost bass control which operates in conjunction with the feedback around the preamplifier stage. This method of bass control provides the required bass action and simultaneously improves the performance of the preamplifier.

The loudness control used in both amplifiers is interlinked with the input-stage feedback loop. As the control is adjusted to vary the voltage gain, it also varies the degenerative feedback to the input stage. Because the amount of feedback below one kilocycle is proportional to frequency, the frequency response of the input stage can be controlled, to a limited degree, by the loudness setting. When the loudness setting is decreased, the feedback becomes proportionately higher at the mid and high frequencies than it is at the low frequencies. In this way, the loudness control and the frequency-sensitive feedback provide a bass-boost action at reduced loudness settings.

In the three-stage amplifier, the tapped potentiometer in the input circuit of the first stage provides an additional bass-boosting action. In this amplifier, the boost from the loudness control (tone controls flat) is 18 db at low control settings. Fig.5 shows frequency-response curves for the three-stage amplifier, and Fig.6 shows curves for the four-stage amplifier.

Basic Design Features

Bias stability in both amplifiers is derived from collector-to-base dc feedback rather than from emitter resistors. This method permits the use of smaller, less expensive electrolytic capacitors. The low saturation currents of the transistors used in the amplifiers insure satisfactory high-temperature performance when this method of bias stabilization is employed.

A conventional approach is employed for the driver-output section of the amplifiers. In this section, a transformerless class B output stage is driven by a transformer-coupled driver stage. A feedback signal from the speaker is coupled back to the input to the driver stage. A phase-correction shunt capacitance is coupled across the feedback resistor to insure stable operation with the output unterminated.

The driver and output stages are conservatively designed with respect to voltage and power dissipation to provide reliable performance under adverse operating conditions. The V_{CER} (collector-to-emitter breakdown voltage for a specified emitter-to-base resistance) test of the 40050 and 40051 transistors is made at 600 milliamperes to insure that no breakdown occurs when phase shift in the output, particularly at low frequencies, tends to cause a flow of current at the peak reverse-voltage point. Heat sinks for the amplifiers, wherever needed, should have as low a thermal resistance as possible to insure that high-temperature performance will be as good as that specified in this note.

The power supply for each amplifier consists of a full-wave rectifier that uses a capacitive voltage divider to provide the required dc voltages. The center of the capacitive divider is grounded so that both positive and negative voltages with respect to ground are provided. Because the dc voltage drop across each

transistor in the output stage is the same, the dc voltage coupled to the speaker terminal is essentially zero. This feature eliminates the need for a coupling capacitor to the speaker. The ripple components to the speaker from the positive and negative terminals of the power supply are equal and out of phase and thus cancel each other.

Applications

The transistor stereophonic amplifiers described in this note are intended for a high-volume commercial market and were designed to meet this objective. They use the full normal spread of gain, saturation current, and other related parameters of commercial RCA transistors. As a result, their interchangeability characteristics are excellent -- i.e., active and passive parts can be replaced with no adverse effects on circuit performance -- and they will operate satisfactorily at ambient temperatures up to 50°C (122°F). These amplifiers can be readily produced in large quantities, and it is felt that they represent commercially feasible circuits for "box" manufacturers to use in the mass production of low-cost transistorized stereophonic amplifiers.

Caution

Because these circuits are designed for operation at high ac and dc voltages, special care must be exercised to insure that no metallic part of the chassis or output transistor is exposed to touch, accidental or otherwise. They should be installed in non-metallic cabinets or properly insulated from metallic cabinets. Potentiometer shafts and switches should make use of insulated knobs.

Table I - Performance Data for 3-Stage, 5-Watt Stereo Amplifier
(at 25°C with 8-ohm load, unless otherwise specified)

Clipping Level (1-kc input)	8	watts

Total harmonic distortion, hum, and noise (with one channel operating at 5 watts):			
loudness setting	maximum	10 db down at 1 kc	
at 100 cps	3.7	2.0	per cent
at 1 kc	3.0	0.83	per cent
at 8 kc	5.0	2.5	per cent

Music power (IHFM rating):

per channel	10	watts
total	20	watts

Sensitivity (full volume, controls flat, input fed through 1000-pf ceramic pickup or equivalent), rms input voltage for 5-watt output:

typical value	0.5	volt
value when transistors in first two stages have betas near low limit	1.0	volt

Interchangeability (sensitivity variation when transistors in first two stages have betas near high or low limits)	±2	db
Stability (high-beta transistors, full bass and treble range, any loudness setting)	no oscillation or motorboating	
Frequency response	See Fig.5	

Hum and noise level:

zero volume	65 db below 5 W (3.6 mv into 8-ohm load)
full volume	60 db below 5 W (6.4 mv into 8-ohm load)

Separation:

at 100 cps	30	db
at 1 kc	40	db
at 8 kc	28	db

High-temperature performance (1-kc input, full volume, to 50°C):

gain variation	<1	db
dynamic range	no premature clipping	

Table II - Performance Data for 4-Stage, 15- or 25-Watt Stereo Amplifier
(at 25°C unless otherwise specified)

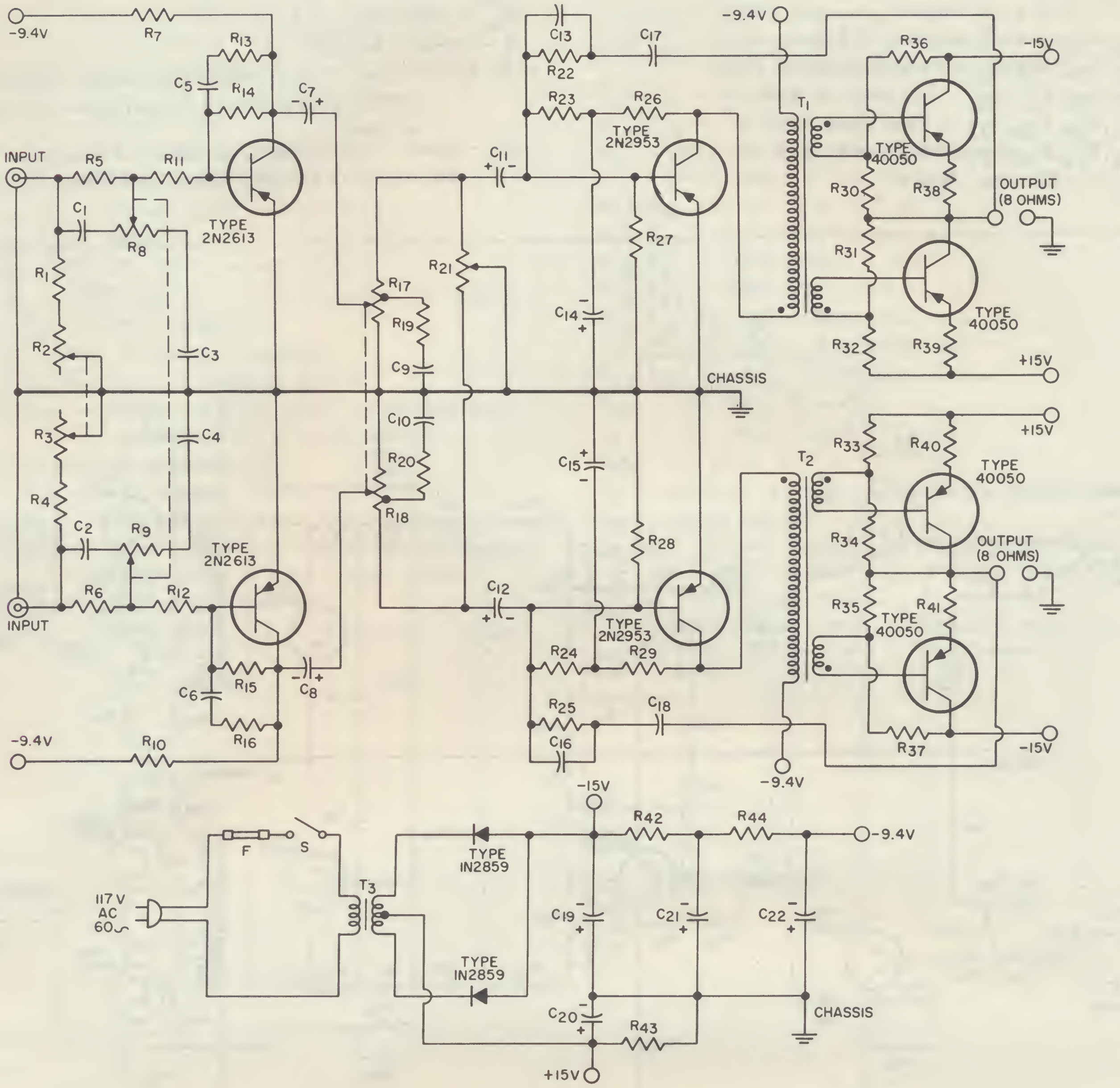
Clipping level (1-kc input):		
for operation into 8-ohm load	15	watts
for operation into 4-ohm load	25	watts

Total harmonic distortion, hum, and noise (with one channel operating into 8-ohm load):	10 db down	20 db down		
loudness setting	at 1 kc	at 1 kc		
power output	15 W	5 W	1 W	
at 100 cps	3.7	2.0	1.1	per cent
at 1 kc	4.1	2.3	1.0	per cent
at 10 kc	9.0	4.0	1.9	per cent

Music power (IHFM rating):	per channel	total	
with 8-ohm load	25	50	watts
with 4-ohm load	37.5	75	watts

Sensitivity (full volume, controls flat), input for 15-watt output:		
with 8-ohm load	0.28	volt
with 4-ohm load	see text	
Interchangeability (sensitivity variation when transistors have betas near high or low limits):		
first three stages	±2	db
all four stages	±6	db*
Stability (high-beta transistors, full bass and treble range, full volume), with 8-ohm load or with no load (output unterminated)	no oscillation or motorboating	
Frequency response	See Fig.6	
Hum and noise level:		
zero volume	65 db below 15W (6.2 mv into 8-ohm load)	
full volume	55 db below 15W (19.6 mv into 8-ohm load)	
High-temperature performance (1-kc input, 15-watt output, to 50°C):		
gain variation	<1	db
dynamic range	no premature clipping	

*Output transistors are grouped and labeled according to their characteristics so that it is possible to use transistors having approximately the same gain in both channels of a stereo amplifier.



C_1, C_2 - 180 pf
C_3, C_4 - 1800 pf
C_5, C_6 - 0.005 μf
C_7, C_8 - 5 μf, 6 v, electrolytic
C_9, C_{10} - 0.47 μf
C_{11}, C_{12} - 4 μf, 3 v, electrolytic
C_{13}, C_{16} - 22 pf
C_{14}, C_{15} - 10 μf, 6 v, electrolytic
C_{17}, C_{18} - 0.001 μf
C_{19}, C_{20} - 1000 μf, 15 v, electrolytic
C_{21} - 100 μf, 15 v, electrolytic
C_{22} - 3000 μf, 10 v, electrolytic (or equiv.)
F - fuse, slo-blo, 1 ampere

R_1, R_4 - 0.1 megohm, 0.5 w
R_2, R_3 - bass control, dual potentiometers, 3 megohms, 0.5 w, audio taper
R_5, R_6 - 0.82 megohm
$R_7, R_{10}, R_{27}, R_{28}$ - 4700 ohms, 0.5 w
R_8, R_9 - treble control, dual potentiometers, 3 megohms, 0.5 w, audio taper
R_{11}, R_{12} - 82000 ohms, 0.5 w
R_{13}, R_{16} - 68000 ohms, 0.5 w
R_{14}, R_{15} - 0.56 megohm, 0.5 w
R_{17}, R_{18} - loudness control, dual potentiometers, 15000 ohms, 0.5 w, linear taper; tapped at 10000 ohms
R_{19}, R_{20} - 470 ohms, 0.5 w

Fig. 1 - Three-Stage 5-Watt-Per-Channel Stereo Amplifier.

R_{21} - balance control, potentiometer, 5000 ohms, 0.5 w, S taper
R_{22}, R_{25} - 0.22 megohm, 0.5 w
$R_{23}, R_{24}, R_{26}, R_{29}$ - 47000 ohms, 0.5 w
$R_{30}, R_{32}, R_{33}, R_{35}$ - 22 ohms, 0.5 w
$R_{31}, R_{34}, R_{36}, R_{37}$ - 1800 ohms, 0.5 w
$R_{38}, R_{39}, R_{40}, R_{41}$ - 0.27 ohm, 0.5 w
R_{42} - 180 ohms, 0.5 w
R_{43} - 560 ohms, 0.5 w
R_{44} - 100 ohms, 0.5 w
S - on-off switch
T_1, T_2 - driver transformers, Columbus Process Co. #7602, Better Coil & Transformer Co. #99A4, or equiv.
T_3 - Power transformer, Columbus Process Co. #X8441, Better Coil & Transformer Co. #99P9 , or equiv.

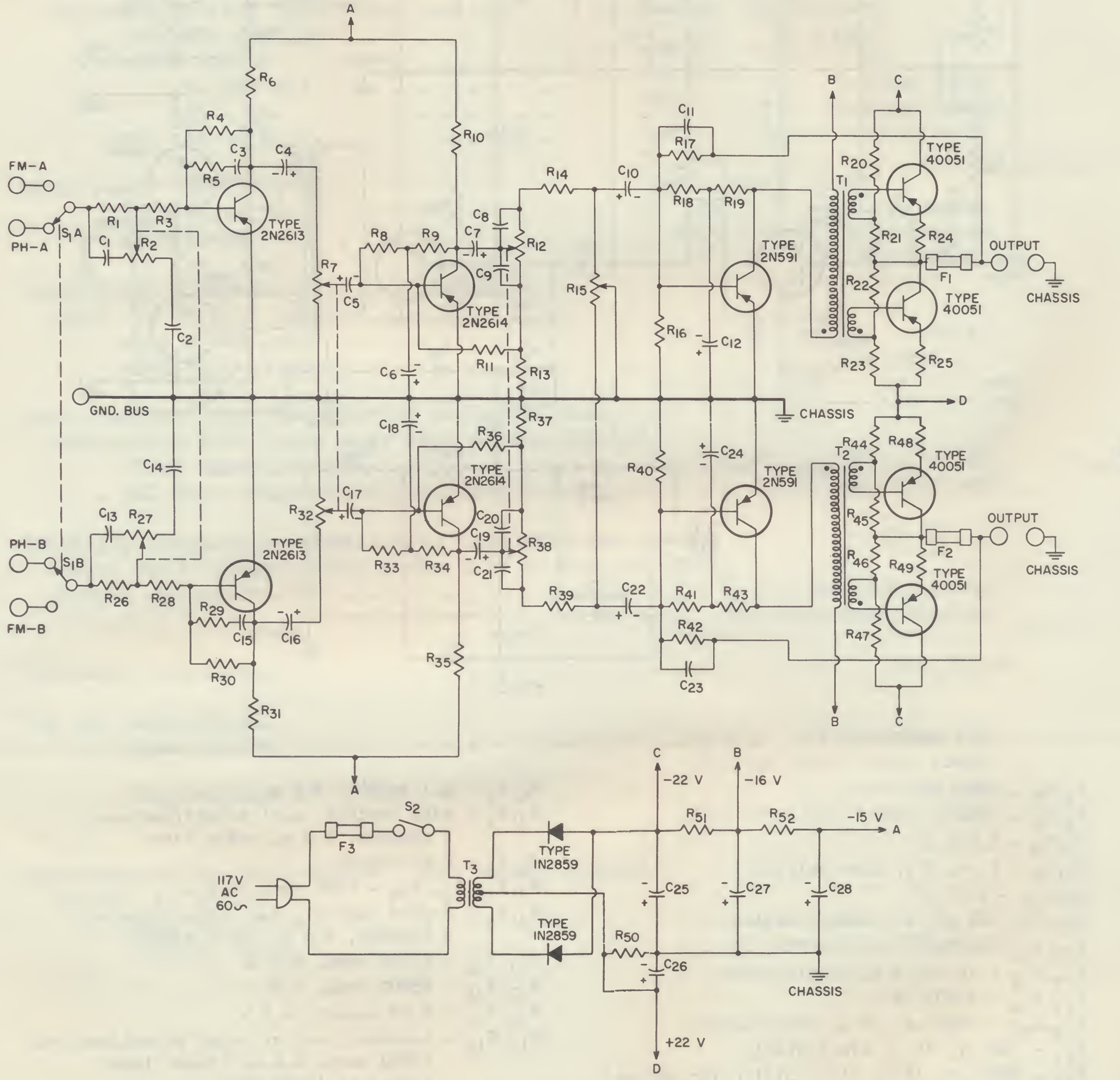


Fig. 2 - Four-Stage Stereo Amplifier That Delivers 15 or 25 Watts Per Channel (to 8-ohm or 4-ohm load impedance, respectively).

PARTS LIST FOR FIGURE 2

C_1, C_{13} - 180 pf
C_2, C_3, C_{14}, C_{15} - 1800 pf
C_4, C_{16} - 2 μf, 10 v, electrolytic
$C_5, C_6, C_{10}, C_{17}, C_{18}, C_{22}$ - 5 μf, 3v, electrolytic
C_7, C_{19} - 5 μf, 10 v, electrolytic
C_8, C_{21} - 0.5 μf $\pm$ 5%
C_9, C_{20} - 4 μf $\pm$ 5%
C_{11}, C_{23} - 47 pf
C_{12}, C_{24} - 50 μf, 3 v, electrolytic
C_{25}, C_{26} - 1000 μf, 25 v, electrolytic
C_{27} - 250 μf, 20 v, electrolytic
C_{28} - 10000 μf, 15 v, electrolytic (or equiv.)
F_1, F_2 - fuse, 3 amperes
F_3 - fuse, slo-blo, 1 ampere
R_1, R_4, R_{26}, R_{30} - 1 megohm, 0.5 w
R_2, R_{27} - treble control, dual potentiometers, 3 megohms, 0.5 w, audio taper
R_3, R_{28} - 0.1 megohm, 0.5 w
R_5, R_{29} - 0.22 megohm, 0.5 w
R_6, R_{31} - 4700 ohms, 0.5 w
R_7, R_{32} - loudness control, dual potentiometers, 25000 ohms, 0.5 w, linear taper
R_8, R_{33} - 27000 ohms, 0.5 w
R_9, R_{34} - 33000 ohms, 0.5 w
R_{10}, R_{35} - 1000 ohms, 0.5 w
R_{11}, R_{36} - 10000 ohms, 0.5 w
R_{12}, R_{38} - bass control, dual potentiometers, 5000 ohms, 0.5 w, audio taper
R_{13}, R_{37} - 39 ohms, 0.5 w
R_{14}, R_{39} - 270 ohms, 0.5 w
R_{15} - balance control, potentiometer, 5000 ohms, 0.5 w, S taper
R_{16}, R_{40} - 1500 ohms, 0.5 w
R_{17}, R_{42} - 0.12 megohm, 0.5 w
R_{18}, R_{41} - 12000 ohms, 0.5 w
R_{19}, R_{43} - 15000 ohms, 0.5 w
$R_{20}, R_{22}, R_{45}, R_{47}$ - 560 ohms, 1 w
$R_{21}, R_{23}, R_{44}, R_{46}$ - 3.9 ohms, 0.5 w
$R_{24}, R_{25}, R_{48}, R_{49}$ - 0.27 ohm, 0.5 w
R_{50} - 330 ohms, 2 w
R_{51} - 100 ohms, 0.5 w
R_{52} - 82 ohms, 0.5 w
S_1 - selector switch, double-pole double-throw
S_2 - on-off switch
T_1, T_2 - driver transformers, Columbus Process Co. X7602, Better Coil & Transformer Co. #99A4, or equiv.
T_3 - power transformer, Columbus Process Co. #7603, Better Coil & Transformer Co. #99P3, or equiv.

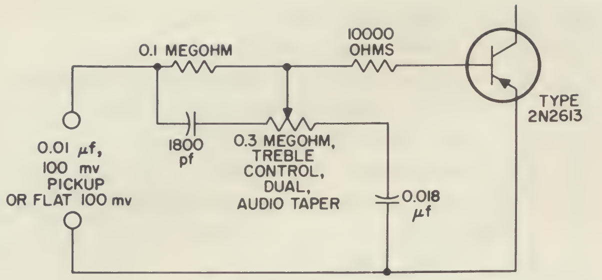


Fig.3 - Input-Circuit Arrangement With High-Capacitance Pickup Used to Obtain Maximum Sensitivity of Four-Stage Amplifier at 25-Watt Operation.

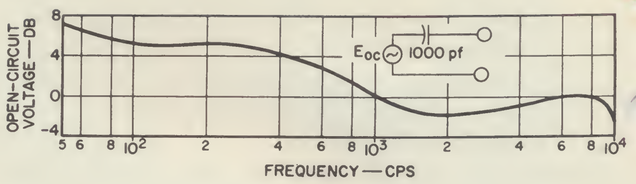


Fig.4 - Equivalent Circuit and Frequency-Response Curve of Typical Ceramic Pickup When Played With RIAA Test Record (0 db = 0.5 v rms at average record). This Equivalent Circuit is Used For Evaluation of Amplifier Response and Sensitivity.

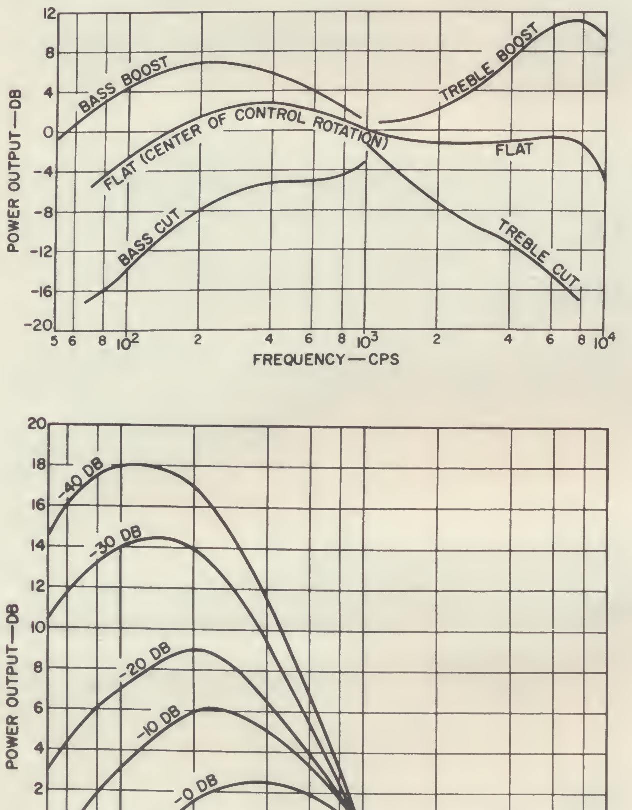


Fig.5 - Frequency-Response Curves for 3-Stage Stereo Amplifier Shown in Fig.1; (a) Full Volume, (b) Loudness Control Down By Amount Shown On Curve; Tone Controls Flat.

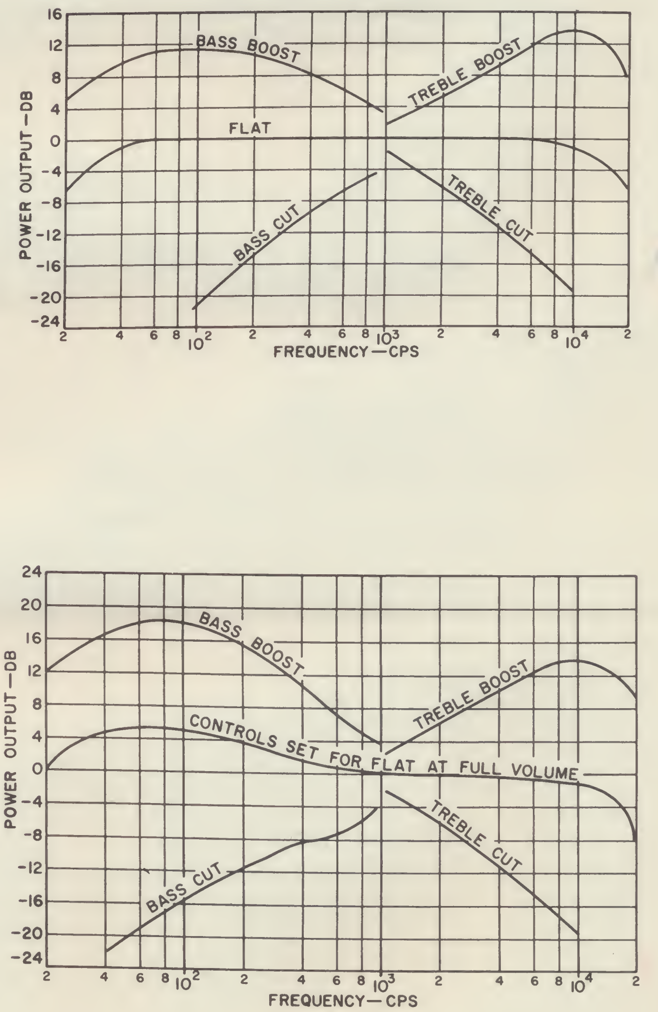


Fig.6 - Frequency-response Curves for 4-Stage Stereo Amplifier Shown in Fig.2; (a) Full Volume, (b) Volume Down 20 db At 1 Kilocycle.